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SURVEY OF CLAY MINERALS IN SOME VICTORIAN SOILS

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While work has been published about the clay mineralogy of soils in other Australian States, the soils of Victoria have not yet been surveyed systematically. Soils have been chosen for the present study so as to include some of the most widely known types, many of which have been examined in the School of Agriculture, University of Melbourne, for their physical or chemical interest. The work has included a detailed study of the range of soils from red to black on the Older Basalt.

Experimental

Preparation of One-Micron Clays

The soil was ground to pass a 1 mm sieve and the organic matter oxidized by an overnight treatment with sodium hypochlorite (12½%) at room temperature (Modification of hypobromite method of Troell (1931)). The sample was centrifuged to remove excess reagent, then shaken and centrifuged first with molar sodium chloride and then with tenth-molar sodium chloride.

The soil was dispersed in water (1500 ml) giving a height of 29 cm in a sedimentation jar. After 3 days the fraction less than one micron was removed by suction, and collected by filtering the suspension on a porous filter candle. The product from the filter candle was dried at 40°C. By this treatment the sample was never heated over 40°C, except for samples submitted to deferration, which were first treated with hypochlorite to remove the organic matter and then with sodium dithionite in a citrate-bicarbonate buffer at 80°C by the method of Jackson (1958). The soil was then washed and dispersed as above.

The resulting clays were ground to pass a 0·2 mm sieve and samples in a standard oblong aluminium carrier were analysed on a Philips X-ray diffractometer, Type PW.1050/PW.1051, using Cu radiations filtered with nickel at the receiving slit. The scatter slit was 1° and the receiving slit 0·1 mm. The power source was adjusted to 800 Watt, i.e. 40 Kv, 20 ma, the goniometer scanning rate was 1° per minute. Routine samples were scanned from 4° 2θ to 65° 2θ. The geiger counter was adjusted to: rate meter 4 or 8, time constant 16 and multiplier 1. For some samples of standard clays the rate meter was made less sensitive. Since clays generally contain much iron, the X-ray patterns are more diffuse with copper than with other sources, but by comparing the traces of samples before and after deferration it was possible to interpret the peaks with some confidence.

Further Treatment of Clays

Additional information was obtained by making use of the following techniques:

1. Heating to 110°C, 550°C and 750°C to decompose minerals selectively.
2. Treatment with glycerol. As a confirmation of montmorillonite and in other doubtful cases, less than 1 micron samples were treated with glycerol overnight and scanned as a paste in the standard carrier.

The identification of the clay minerals from the standard literature was checked with the standard clays supplied by Ward's Natural Science Establishment, Inc. No attempt has been made to particularize the illite beyond its identification by the 10 A and minor peaks and by its non-swelling nature. The disorder of the kaolinite noted in samples 4 and 7 was judged by the gradual slope on the upward peak of the 7 A line.

Discussion

The results of the general survey are given in Table 1.

Soils 1 and 2 represent the best-known agricultural soils of their respective districts. These northern soils, with the drier climates and higher pH, are illitic. The southern soils, with the wetter climate and lower pH, are kaolinitic. These include No. 4 (in the Kooweerup basin), No. 5 (in a basin among Silurian hills), No. 6 (on Silurian mudstone, with some muscovite surviving from the parent rock), No. 7 (on granodiorite; no mica survives into the fine clay), No. 10 (on Pliocene basalt) and No. 12 (on Eocene basalt). The other kaolinitic sample, No. 3 (a sub-soil from the Murray riverine plain), may be a Tertiary deposit and was included because of its extreme sub-plastic properties, which are compatible with a composition of kaolinite and ferric oxide. Non-kaolinitic southern soils comprise the juvenile soil on the Jurassic sandstone of South Gippsland (No. 8), and two soils on Pleistocene basalt from the drier Western District. Turkeith clay (No. 11) is from a gilgai formation a few miles N. of Mt Gellibrand. The other basaltic clay (No. 13) is dealt with at more length below.

A detailed study has also been made of the soils formed on the 'Older' (early Tertiary) basalt of South Gippsland and the E. Central District. While the typical soil in Gippsland is a red-brown clay loam overlying a friable red clay to a depth of several feet (Table 1, No. 12), contrasting soils occur on these older basalts as at Berwick and Phillip Is. The extreme contrast (Table 1, No. 13) is a black friable clay at the surface, with a subsurface clay that swells and cracks with the changing seasons, and passing at the third foot into a gritty clay. This gritty clay contains the primary minerals of the basalt in its sand fraction (plagioclase, augite, olivine weathering to serpentine, as was kindly determined by Dr G. Baker, Mineragraphic Investigations Section, CSIRO). For further study here, additional profiles were sampled at Berwick and at Phillip Is., as well as from the main basalt plateau at Leongatha (Table 2).

The red soils (12, 14, 15, 16) consist of kaolinite and ferric oxide, though the weathering rock from a cutting at Leongatha contains illite as well. The grey and black soils include not only the montmorillonitic member already mentioned (13) but intermediate profiles (17, 18). No. 18 contains kaolinite, but otherwise resembles 13, with its decomposing primary minerals in the third foot. No. 17 has no 2:1 clay in the surface, but contains some in the subsoil. The existence of these intermediate profiles agrees with the description of the basalt soils of Berwick by Holmes et al. (1940), who mapped them either as 'red-brown' (those with bright red colours and friable clays below) or as 'black' (including intermediate colours and properties of clay).

The 'red' and 'black' samples occur close to one another. For example, No. 18 was collected on the same hill as No. 12, both of them near the top of the ridge that runs between Berwick and Beaconsfield.

Similar ranges of soil on basalt have been described and discussed in N. New South Wales by Hallsworth et al. (1952) and in S. Queensland by Teakle (1952) and Ferguson (1954).

TABLE 1

Clay Minerals in the Fraction below One Micron

Soil	District	Depth Inches	Texture or % elay	pH	Clay Minerals (Other Constituents in Parentheses) ‡
1. Tatchera sandy loam	Mallee	18	sandy clay	9·0	Illite (Ca, H)
2. Horsham clay	Wimmcra	0-6	clay	7·4	Illite (Q)
3. Katamatite loam	Goulburn Valley	45	63	9·1	Kaolinite
4. Dalmore clay	E. Central	0-6	67	5·1	Metahalloysite, Kaolinite (d)
5. Eumemmcring elay	E. Central	0-6	48	5·5	Kaolinite (d) (H, Q)
		33-42	66	6·7	Kaolinite (d) (H, Q)
6. Hallam loam	E. Central	0-8	21	4·7	Muscovitc, Kaolinite (Q)
		18-30	73	4·7	Muscovite, Kaolinite
		30-44	55*	4·6	Muscovite, Kaolinite Chlorite
7. Harkaway sand	E. Central	15-20	55	5·2	Kaolinite (d)
		22-30	25*	5·5	Kaolinite (d)
8. Grey Loam† on Jurassic sandstone	S. Gippsland	0-6	loam	5·1	Illite (Q)
		24	—*	5·7	Illite, Kaolinite
Newer Basaltic Soils					
9. Red-brown clay loam	W. Central	12	59	6·2	Illite, Kaolinite (H, Q) Kaolinite (Q)
10. Buckshot Plains	Western	8-12	clay loam	5·6	Kaolinite (H, Q)
		18-40	clay	5·6	Beidellite Illite
11. Turkeith clay	Western	0-7	58	8·1	Kaolinite (tr.)
		54-66	49	8·6	Beidcllite Illite Kaolinite (tr.)
Older Basaltic Soils					
12. Red-brown clay loam	E. Central	0-9	36	5·1	Kaolinite (H, Q)
		27-39	79	5·6	Kaolinite (H, Q)
13. Black friable clay	E. Central	6-12	clay	4·9	Montmorillonite, Illite (tr.) (I.O., M)
		24-30	sandy elay*	6·6	Montmorillonite, (P(tr.))

* Decomposing roek.

† According to evidcnee presentcd in this number (Dettmann 1963) these sediments are to bc assigned to the lowcr Crctaeeous.

‡ Ca = calcite; H = hcmatite; I.O. = beta FeO.OH; M = magnetite; P = plagioclase; Q = quartz.

Referenees: 1. Taylor & Penman (1930); 2. Skene (1959); 3. Skcne & Poutsma (1962); 4. Goudie (1941); 5, 6, 7, 12, 13. Holmes et al. (1940); 9. Werribee State Rcsearch Farm; 10. Leeper (1948); 11. Lecpcr ct al. (1936).

Fcrguson, working near Toowoomba, finds montmorillonitc in black soils and kaolinite in red soils and both together in some intermediates. Hc acccpts thc usual sequence in wcathering, with montmorillonite being formed first and brcaking down finally to kaolinite and ferric oxide. According to him the young montmorillonitic soils can form only whcn erosion has removed the more weathered material.

Teakle's explanation is similar. He regards the red kaolinitic soil as stable once formcd, so that geological erosion would be needed before a black soil could form on that rock. But he also attributes some stability ('pedogenic inertia') to the montmorillonitic clay once it is formed, since it is too impermeable to be leached. The disappearance of the 2:1 clay from the surface of sample 17 (Table 2) does not fit this opinion. The black soils of his study contain free $CaCO_3$, which is absent from the black profiles of Berwick, and detected in small amounts in the subsoil of No. 17.

TABLE 2

Range of Soils on Older Basalt

Clay Number	Location	Depth Inches	Soil Texture	Soil Colour	pH	Clay Minerals (Other Constituents in Parentheses)†
Red and Red-brown Soils						
12a	Berwick	0-9	clay loam	2·5YR 3/2	5·1	Kaolinite (H, Q)
b		27-39	clay	2·5YR 3/6	5·6	Kaolinite (H, Q)
14	Berwick	24	clay	10R 3/4	6·5	Kaolinite (H)
15	Phillip Is. (David Forest)	24	clay	2·5YR 3/4	6·5	Kaolinite (G, H)
16a	Leongatha	18	clay	2·5YR 3/4	6·5	Kaolinite (G, H)
b		60	clay*	2·5YR 3/4	6·4	Metahalloysite, Illite, Kaolinite (tr.)
Grey and Black Soils						
17a	Phillip Is. (Nobbies)	0-6	clay	10YR 3/2	6·7	Metahalloysite (G, H, Q (tr.))
b		18	heavy clay	10YR 3/2	6·9	Metahalloysite, Illite, Kaolinite, Montmorillonite (tr.) (Ca, G, H)
18a	Berwick	6-12	clay	10YR 3/1	5·4	Montmorillonite, Kaolinite (tr.)
b		24-30	clay*	25Y 4/1	6·6	Montmorillonite, Kaolinite (tr.)
13a	Berwick	6-12	clay	10YR 3/1	4·9	Montmorillonite, Illite (tr.)
b		24-30	sandy* clay loam	10YR 3/2	6·6	Montmorillonite (P(tr.))

* Decomposing rock.
† Ca = calcite; G = goethite; H = hematite; P = plagioclase; Q = quartz.
Reference: 12, 13, 14, 18. Holmes et al. (1940).

Hallsworth (1951) also found intermediate types containing illite, as might well be expected. He explains reds and blacks in terms of catenas with red on the upper eluviated slopes, black on the lower illuviated slopes. Such a picture does not apply to Berwick and Phillip Is., where black soils as well as red occur on ridges.

From this work it appears that the constituents of the soils on the older basalt favour the theories of Ferguson that the ultimate products of weathering are kaolinite and ferric oxide and that montmorillonite occurs where the rock has been exposed by erosion.

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